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The origins of human embryonic stem cell research policies in the US states

Aaron D. Levine[1,*], T. Austin Lacy[2] and James C. Hearn[3]

[1]*School of Public Policy, Georgia Institute of Technology, 685 Cherry Street, Atlanta, GA 30332-0345, USA*
[2]*University of North Carolina – General Administration, 910 Raleigh Road, Chapel Hill, NC 27514-3916, USA*
[3]*Institute of Higher Education, University of Georgia, Athens, GA 30602-6772, USA*
**Corresponding author. Email: aaron.levine@pubpolicy.gatech.edu.*

Stem cell research has emerged as a state-level science and technology policy issue in recent years in the USA, with some states supporting research in the field and others choosing to restrict it. In this paper, we systematically explore the factors that are associated with US states' adoptions of both supportive and restrictive stem cell policies. Our analysis identifies several factors, including partisan politics, existing morality policies, the strength of a state's scientific community and the policy environment in neighboring states, which influence the adoption of state stem cell policies. Our paper aims to advance the science and technology policy literature by providing insight into the factors that push states to adopt science policies when economic development goals conflict with ethical concerns.

Keywords: stem cell policy; policy adoption; morality policy; economic development policy; state science and technology policy.

1. Introduction

Although the adoption of policy innovations by the various US states has received substantial attention from political scientists (Berry and Berry 1990, 1992; Gray 1973; Walker 1969), the adoption of state science and technology policies has received less attention. Here, we examine the adoption of state policies related to human embryonic stem cell (hESC) research.[1] Given ongoing policy debates over hESC research, this research has substantial applied interest. It is also of theoretical interest as, unlike most cases of policy innovation studied to date, states addressing stem cell policy have three distinct options: actively supporting hESC research, deliberately restricting it or remaining silent on the subject. Choosing to support or restrict hESC research is arguably a form of morality policy and, as such, the adoption of these policies may be expected to reflect the influence of factors seen in the adoption of abortion (Mooney and Lee 1995) or death penalty policies (Mooney and Lee 1999, 2000). At the same time, supportive stem cell policies have implications for economic development, suggesting that a different set of factors might motivate adoption. Comparing the adoption of supportive and restrictive stem cell policies offers a unique opportunity to advance our understanding of state-level science and technology policy and provide insight into key factors that influence policy adoption when moral and economic imperatives conflict.

2. The emergence of state stem cell policy

Two scientific breakthroughs in the late 1990s, the cloning of mammals (Wilmut et al. 1997) and the successful isolation of hESC lines (Thomson et al. 1998), set the stage for novel science policy debates at both the national and state levels. These ongoing debates center on the combination of hope and controversy these scientific advances inspired. Research on hESCs is thought by many scientists to offer substantial promise to improve our understanding of human disease and eventually help develop treatments for currently untreatable conditions. This research is

controversial, however, because the derivation of hESC lines requires the use, and typically the destruction of, early human embryos. In addition, if hESC research is to reach its full potential, it may require the use of cloning technology to create embryos genetically matched to potential patients, a technique known as therapeutic cloning.[2] This technique, which has been demonstrated in animal models, but remains hypothetical in humans, inspires controversy because it is seen as opening the door to the cloning of human beings for reproductive purposes.

Policy responses to these scientific advances took many forms and occurred at different levels. In the USA, the day that the birth of Dolly—the first mammal cloned from an adult cell—was announced, President Clinton banned the use of federal money for the cloning of a human being. This complemented an existing legislative restriction—the Dickey–Wicker Amendment—that banned the use of federal money for research in which human embryos were harmed.[3] Legislative attempts to ban human cloning regardless of funding source have not been passed in the USA, largely because of disagreement over the issue of therapeutic cloning. This has left the USA as one of the few developed countries without an explicit ban on human reproductive cloning and may have served as one motivation for state policy restricting cloning and, potentially, stem cell research.

The successful isolation of hESCs in 1998 also inspired policy action at the federal level. Following a legal review that concluded that the federal government could legally fund hESC research as long as federal funds did not support the actual derivation of the cell line(s) studied, the Clinton Administration issued guidelines in August 2000 supporting research in this field (*Federal Register* 65[2]: 51976–81) and the National Institutes for Health (NIH) put out a call for applications inviting scientists to apply for research funding (Johnson and Williams 2004). Between the adoption of this policy and the first meeting to review grant applications under the new guidelines, US voters elected a new president, George W. Bush. Following the election, the Bush Administration initiated changes in federal policy toward hESC research, putting the Clinton Administration policy on hold, and cancelling the first meeting to review pending grant applications (Weiss 2001). Later, President Bush addressed hESC science in a primetime address to the nation, announcing a new policy that restricted federal funding for hESC science to research on cell lines that existed at the time of his speech (Bush 2001). In the public sphere, the limitations this policy imposed on stem cell scientists have been suggested as a potential motivation for states to adopt policies that support stem cell research.

In 2009, the Obama Administration relaxed some of the previous administration's restrictions on federal funding for hESC science (*Federal Register* 74[128]: 32170–5). These changes included the elimination of the temporal restriction central to the previous policy and federal funding may now be used on ethically derived hESC lines regardless of the date of derivation. Implementation of this policy has been hindered by legal challenges, however, and substantial uncertainty persists regarding the future of federal funding in this field (Gottweis 2010; Levine 2011a).

Within this national policy context, state stem cell policies have taken many forms. States have adopted restrictive policies ranging from bans on any embryo-destructive research to bans on specific research practices (e.g. the creation of cloned human embryos for any purpose, including research) to restrictions on the use of state funding for research in this field. Although the severity of the restrictions these policies impose on hESC science varies, in the analysis that follows we categorize each as a restrictive stem cell policy. States have adopted supportive policies ranging from explicitly legalizing hESC research and the creation of cloned human embryos for research purposes to the provision of state funding to support research in this field. Thus far, six states have taken this latter option and adopted programs designed specifically to fund hESC research. Although we recognize that these various options could have different impacts on hESC research, in the analysis that follows, we categorize each as a supportive stem cell policy. We acknowledge the existence of important differences in the specific details of each restrictive and supportive policy, but, following a long tradition in the policy adoption literature (Berry and Berry 1990), seek to identify underlying similarities among states that are systematically related to the adoption of a general class of policies.

The rise of stem cell research as a state policy issue over the last decade has inspired a small but growing body of literature. This work has examined policy differences between states with an eye to facilitating interstate collaborations (Lomax and Stayn 2008; Stayn 2006), assessed the impact of state policies on scientist mobility (Levine 2006, 2008, 2012), and the use of key research tools, such as hESC lines (Levine 2011b; McCormick et al. 2009), and evaluated the return on investment that states might receive from a supportive stem cell program (Longaker et al. 2007).

Less work has focused specifically on the development or adoption of state stem cell policies. Fossett et al. (2007) have argued that state policy action works well in an environment of moral pluralism as it permits 'a better fit between public opinion and public policies.' In addition, Mintrom and Bollard (2009) have used stem cell research as lens through which to draw lessons for the governance of controversial science and Mintrom (2009) has examined the development and consequences of the patchwork of state stem cell policies that emerged during the George W. Bush Administration. This latter paper contains a series of bivariate analyses of factors, such as partisan control of state legislatures, political party of the governor, and the religious affiliations of a state's citizens, that may be associated with the adoption or consideration of state policies funding

stem cell research and provides an important context for the analysis reported here. Karch (2012) has used the introduction of stem cell-related bills in state legislatures as a tool with which to understand the agenda-setting process and finds that national government activities, such as President Bush's August 2001 speech, have a strong impact on the introduction of stem cell related bills at the state level. Karch also finds that state attributes have only a limited effect on bill introduction, but notes that the factors associated with bill introduction and policy adoption might differ. Our study builds on Karch's work on agenda setting, by addressing not which policies have been introduced—a relatively low bar—but which have actually been adopted by the various states.

We aim to extend this literature base through a more systematic consideration of the factors that have influenced adoption of both supportive and restrictive state stem cell policies. Understanding the adoption of state stem cell policies is important given the prominent role these policies are playing in the development of the field (Karmali et al. 2010), particularly considering the ongoing uncertainty over federal funding in the USA. In addition, this analysis offers the opportunity to advance the policy adoption literature more generally through the consideration of how policy adoption proceeds when economic and moral imperatives conflict and states are provided with multiple policy choices.

3. Conceptual framework

Drawing on existing literatures on policy adoption and on state science and technology policy, media reports, as well as discussions with officials in state stem cell programs, we have identified a range of factors that are likely to be associated with the adoption of supportive state stem cell policies, restrictive state stem cell policies, or both.[4] These factors include political considerations, the state's policy environment in other morally contentious areas, the strength of a state's scientific community, characteristics of the state's economy and its citizens, and the policy environment in neighboring states. The selection of these factors reflects a belief that attempts to understand policy choices made by state governments should account for both the characteristics of each individual state—sometimes termed internal or intrastate determinants—and the potential influences that one state may exert over another's policy action—sometimes termed external or interstate determinants.

In the remainder of this section, we explain our rationale for including these factors in our analysis and, when feasible, offer preliminary hypotheses about the directionality of potential impacts. Given the relative dearth of existing empirical data on the adoption of state science and technology policies and the conflict between morality and economic development policies inherent in the adoption of state hESC policies, we cannot predict, a priori, the precise directionality of all effects. Rather, we can envision competing rationales for some factors and, in these cases, we outline the competing effects that we envision.

First among our potential explanatory variables are state-level political characteristics. Drawing on observations of the political debate over stem cell polices at the national level where President Bush was closely associated with restricting hESC science, we hypothesize that Republican governors and Republican-controlled legislatures will be more likely to adopt restrictive stem cell policies. Conversely, we hypothesize that Democratic governors and Democrat-controlled legislatures will be more likely to adopt supportive policies.

We believe the party of the governor and partisan control of the state legislature both have the potential to be important determinants of state action on stem cell science. We cannot say in advance, however, if executive or legislative power is likely to be more important in the adoption of supportive or restrictive state stem cell policies. Given the contentious nature of stem cell policy, we can envision a role for strong policy entrepreneurs in the adoption of these policies (Mintrom 1997) and it seems plausible that governors could take on this role. The set of powers granted to the governor varies by state (Beyle 2004) and it may be the case that only strong governors can successfully push their states to adopt policies either supporting or restricting stem cell science. For this reason, we include an index of the strength of the governor's institutional powers in a given state in our analysis and interact this variable with the governor's political party.

We can also envision a scenario, however, where stem cell policy is too contentious for governors and policy action falls to state legislatures. Previous evidence suggests that politicians are particularly attuned to public opinion in areas of morality policy (Mooney and Lee 1999) and we can envision that state legislators, with their smaller and typically more homogeneous districts, may drive policy action in this area in response to constituent demands. Drawing on literature from state higher education policy exploring the role of transitions in legislative control on policy adoption—termed the political instability hypothesis (McLendon et al. 2007)—our legislative variables focus on the takeover of state legislatures by either Republicans or Democrats.

In addition to the political affiliations of elected officials, the characteristics of the citizens of each state may also affect the adoption of stem cell policies. We consider two such characteristics—the ideology and the education level of a state's citizens. Specifically, we include the measure of citizen ideology developed by Berry et al. (1998) in our model and hypothesize that the adoption of supportive stem cell policies will be associated with more liberal state populations and the adoption of restrictive stem cell policies will be associated with more conservative state

populations. In addition to following the general contours of the policy debate at the national level, we are led to these hypotheses because state support of stem cell research often includes the expansion of governmental responsibilities, classically a liberal position, while restriction of stem cell science is often linked to policies restricting abortion, a position typically associated with more conservative citizens. We note, however, that, although most public opinion surveys on stem cell research find a partisan split with greater support among self-identified Democrats, polls often find substantial cross-over support by Republicans (Pew Research Center 2009). These data, along with evidence of greater partisanship among political elites than the general public (Fiorina and Abrams 2008), suggest that the variables related to the partisanship of elected officials might matter more than citizen ideology. Following Mintrom (2009), we also include a measure of the education level of a state's citizens in our model. We hypothesize that states with a higher share of citizens with college degrees will be more likely to adopt supportive policies and less likely to adopt restrictive policies.

In popular debates, hESC research is often linked to abortion and we believe that state stem cell policy choices may be linked to state abortion policy. This relationship may reflect a direct link between stem cell and abortion policy in the policy process or may operate indirectly, with abortion policy serving as a proxy for a particular type of social conservatism we believe to be related to stem cells. To examine this relationship, we include an index of abortion access produced by NARAL Pro-Choice America in our models. This index measures how easy or difficult it is for women to access abortion services in each state. We expect that states with more restrictions on this access will be more likely to adopt restrictive hESC research policies.

We also believe that the strength of a state's scientific community and, in particular, the amount of funding a state's scientists attract from the federal government may influence that state's adoption of policies affecting stem cell science. We include two variables designed to assess this influence. Specifically, we hypothesize that states with a large number of strong research institutions, or that receive more per capita funding from the NIH, will be less likely to restrict research on hESCs. These hypotheses derive from our expectation that state policy-makers would be hesitant to take action that might place their state's successful scientific enterprise in jeopardy and reduce the amount of federal dollars flowing to their state. Our focus on the number of institutions, rather than the total dollar amount, is related to our hypothesis that these institutions have a vested interest in these policies and thus are potential actors in the policy process. We also expect that states with strong scientific communities would be more likely to adopt supportive policies. This could be the case for several reasons. These states may seek to capitalize on their strong position and help their scientists assume leading roles in stem cell science. Alternatively, they could be acting defensively, seeking to protect their scientists from poaching by other states, a concern given the increased mobility seen among stem cell scientists, compared to scientists in other biomedical research fields (Levine 2006). We operationalize these measures based on total federal R&D funding and total NIH funding, respectively, rather than funding for stem cell research, both to accurately capture our beliefs about how scientific strength may affect the policy process and because federal restrictions affected the funding allocated to stem cell research during the years of our study.

In addition to federal funding of science, we believe that a state's own contribution to R&D activities may affect its policies toward stem cell science. States with large per capita investments in R&D have signaled their beliefs in the importance of science and technology and may be more likely to adopt supportive stem cell policies. For the case of restrictive policies, we hypothesize that states with large per capita investments in R&D would be less likely to adopt policies restricting hESC as they may limit the effectiveness of the state's existing R&D investments by, for instance, hindering the ability of the state's scientists to attract external funding. Numerous states have, for example, adopted eminent scholars programs to recruit star scientists to their state (Hearn et al. forthcoming) and these states might be hesitant to adopt a restrictive stem cell policy that could limit the ability of some of these state-funded scientists to conduct their research.

In addition to a state's own contribution to R&D, the role of innovation in the state's economy may also influence the adoption of stem cell policies. To test this hypothesis we include the number of patents per 10,000 citizens in our analysis. We expect states with more patents per capita to be more likely to adopt supportive policies and less likely to adopt restrictive policies.

The larger economic picture in a state may also influence the adoption of stem cell policies, although the direction of this influence is not entirely clear. It may be the case, in line with existing literature (Berry and Berry 1990), that states with strong economies (measured here by the gross state product (GSP) per capita) are more likely to adopt new programs, including those supporting stem cell science. Alternatively, states with weaker economies may see stem cell science as an opportunity and adopt supportive policies as a strategy to spur economic growth.

Beyond these political, scientific and economic characteristics that are internal to individual states, we recognize that factors outside of a state may also influence policy adoption. Here we focus particularly on the policy environment in neighboring states, following others (Berry and Berry 1990) in theorizing that state policy-makers may both learn from the experiences of nearby states, face pressure from their constituents to adopt policies that exist in neighboring states, or address a perceived competitive disadvantage. Most often, studies examining this sort

of policy diffusion specify this hypothesis as how the adoption of a specific policy is influenced by the prior adoption of the same policy in neighboring or nearby states (see Doyle 2006 on merit scholarships; McLendon et al. 2006 regarding performance funding). Because states have adopted policies that both support and restrict stem cell science, we are able to address a more nuanced set of questions assessing the influence of the adoption of both supportive and restrictive policies in neighboring states.

Given the novelty of this particular diffusion model, we find only limited guidance in the extant literature to frame our hypotheses. Although Karch (2012) did not find a neighboring state effect in his study of stem cell bill introduction, we believe that the actual adoption of either supportive or restrictive policies in neighboring states could play an agenda-setting role, raising the issue of stem cell research on a state's policy agenda. In this scenario, policy adoptions in neighboring states might be expected to increase the likelihood of the adoption of both supportive and restrictive stem cell policies. In addition to agenda setting, state policy adoption may be influenced by both policy learning and competition between states. The adoption of a restrictive policy that is generally well-received and popular in a neighboring state may encourage the adoption of a similarly restrictive policy. Conversely, if a restrictive policy is perceived as poorly designed, associated with hindering a state's economy, or the source of contentious debates, it may discourage the adoption of similar policies in neighboring states and perhaps even encourage the adoption of supportive policies.

Competition between states seems likely to be most relevant to the adoption of supportive state policies. We expect, for instance, that states will be more likely to adopt supportive policies if their neighbors have already adopted similar policies. This hypothesis derives from the idea that state policy-makers will see the adoption of supportive policies in neighboring states as a threat and adopt supportive policies of their own to help protect their scientific community and discourage their top scientists from leaving. This hypothesis also derives support from anecdotal reports suggesting that such competitive behavior exists in this field. Before New York adopted its own supportive program, scientists in New Jersey, for instance, talked of recruiting top scientists from neighboring New York (Mansnerus 2005) and former Illinois Governor Rod Blagojevich sent letters to stem cell scientists in neighboring Missouri encouraging them to explore the possibility of moving to Illinois (Hampel 2005). We also hypothesize that the presence of restrictive policies in neighboring states may also promote the adoption of supportive policies. Here, rather than protecting their scientific community, states may be acting opportunistically by deliberately making their state a center for this research, compared to more restrictive neighbors. Given recent evidence that stem cell scientists in restrictive states are particularly mobile (Levine 2008), adopting a supportive policy when neighbors are restricting this research would presumably put a state in a strong position to recruit scientists from its neighbors.

4. Research design

For this analysis, event history analysis (EHA) was used to examine the factors that influence the timing of states' adoptions of supportive and restrictive stem cell policies. Increasingly, researchers of comparative state policy adoption have turned to this class of models to study phenomena with discrete outcomes occurring across time (Berry and Berry 1990; McLendon 2003; Mooney and Lee 1995). Recently, this approach to policy adoption has been used for the study of post-secondary education policies (Doyle 2006; McLendon et al. 2006) and their intersection with science and technology policies (Hearn et al. forthcoming).

Our sample includes a total of 47 states over a time period of 11 years. Alaska and Hawaii are removed due to their absence of proximate neighbors and our interest in contiguous diffusion. Nebraska, in turn, was omitted because of the state's unicameral and non-partisan legislative system.[5]

Our analysis consists of two models: one for restrictive stem cell policies and another for supportive stem cell policies. While at first these seem inextricably linked, as outlined in our conceptualizing of these policies, we propose that stem cell policy is the field, with restrictive policies falling into the class of morality policies and supportive policies into the wider type of economic development policies. If this is true, the latter makes specifying a single model for both policies particularly challenging as stem cell funding is not exhaustive of the economic development policies available to states (e.g. R&D tax credits, eminent scholars policies, research parks). Beyond this conceptual shortcoming, our approach leaves open the possibility that a state could first adopt either a supportive or restrictive policy and later change course, adopting a more supportive policy. Such policy switches occurred twice in our dataset, with both Michigan and Iowa changing from restrictive stem cell policies to supportive policies.[6]

The data for the dependent variables, the year in which each state first adopted a policy either supporting or restricting hESC research, were collected from the website of the National Council of State Legislatures, which regularly tracks laws that affect embryonic and fetal research (see <http://www.ncsl.org/default.aspx?tabid=14413> accessed 6 February 2013) and cross-referenced with other scholarly sources (Andrews 2004). The date of policy adoption was verified through official state organizations and legislative records. Policies were considered supportive if they provided state funding for stem cell research, including

research on hESCs, or took steps to legalize hESC research and related techniques, such as therapeutic cloning. Policies were considered restrictive if they explicitly banned research on hESCs, placed restrictions on relevant techniques or limited the use of public funds for hESC-related research. Policies that focused exclusively on adult stem cell research and did not influence hESC research were excluded from our analysis.

In undertaking across-state analysis of policies in this domain, we take into account the reality that policies categorized as supportive or restrictive may differ in their approach to supporting or restricting the field, in the magnitude of their effects on the field, and in the details of their adoption. Some policies, for example, were adopted legislatively, while others were adopted through statewide votes. Strong policy entrepreneurs played an important role in some states, but not in others. We hypothesize, however, that there are underlying socioeconomic, educational, and political factors, that prompt states to action in this policy domain and that these factors can be discerned and studied without paying attention to detailed differences among the states' policies.

The independent variables in this analysis reflect the propositions discussed previously: partisan takeover of the state legislature, political party of the governor, institutional powers of the governor, citizen ideology, educational attainment of the state's citizens, the number of institutions high in federal R&D funding, NIH funding per capita (lagged and logged), state R&D expenditures per capita (lagged and logged), patents per 10,000 citizens (lagged and logged), GSP per capita (lagged and logged) and the number of neighboring states that had previously adopted a supportive or restrictive stem cell policy. The decision to lag many of the variables one year is based on the timing of state legislative sessions. Because these sessions are typically held at the beginning of a calendar year, policy-makers would have access to only the prior year's data on a state's economic climate and research enterprise. The data for these variables were collected from a variety of reliable secondary data sources, such as the Bureau of Economic Analysis and the National Science Foundation. Table 1 provides a description of each of these variables with the source of the data.

In our analysis, time is measured discretely as the calendar year in which a state first adopted a stem cell policy. Our data set begins in 1998, when Rhode Island adopted a supportive policy and Michigan adopted a restrictive policy, and continues until 2008, by which time a total of 12 states had adopted supportive policies and eight states had adopted restrictive policies. We chose 2008 as the endpoint for our analysis due to the change in federal policy associated with the election of President Obama and our belief that this changing national policy environment may affect the dynamics of state policy adoption in this field.

The dependent variable expresses the duration of time in years (t) until a state (i) adopts a hESC research policy. First, we calculated the survival function, representing the probability that a unit will 'survive' (or fail to experience the event) longer than time t (Box-Steffensmeier and Jones 2004). Next, we calculated the hazard function which represents the instantaneous rate of change in the probability of experiencing an event at time t, conditional upon 'survival' up to the specified period of time.

To test our hypotheses, we use the Cox proportional hazards model. The Cox model provides several advantages to other EHA estimators (see Jones and Branton 2005 for a discussion of these advantages). First, the Cox model uses the ordered failure times of the event in question focusing on the relationships between the covariates and the outcome of interest, importantly, allowing the avoidance of distributional statements related to duration (Box-Steffensmeier and Jones 2004). Given our decision to run two distinct models, this allows us to have some congruence between them, yet allows for the distinct differences in the patterns of adoptions of these policies.

The following equation expresses our models related to the adoptions of stem cell policies:

$$h_i(t) = h_0 \exp(\beta' x)$$

where $h_i(t)$ is the hazard of adopting a stem cell policy for state i in year t, and $\beta' x$ is the matrix of regression parameters and covariates (Box-Steffensmeier and Jones 2004; Hosmer and Lemeshow 1999). To account for the occurrence of tied events in both of our models the Efron method was used. We selected the Efron method for its ability to allow us to use robust variance estimators, a correction we believed needed to be done a priori.

After specifying the initial model, we ran diagnostics to test the proportional hazards assumption, an assumption which, if violated, can lead to serious problems in inference (Box-Steffensmeier and Zorn 2001). In order to test this assumption, Schoenfeld residuals were calculated to determine whether the effect of any of the covariates changed disproportionately over time (Grambsch and Therneau 1994). These diagnostics suggested that in the analysis of the adoption of supportive policies, the number of strong research institutions variable and the state R&D expenditures variables both violated the proportional hazards assumptions of the Cox model. One possible means for satisfying this assumption is to interact the offending variable with some form of time, and repeat the diagnostics. In the absence of any theoretical basis for selecting a particular shape of the time component to the interaction, we used the natural log of time, where $t = 1$ in the first year of the model. Additional diagnostic methods were conducted including an assessment of the overall model fit using Cox–Snell residuals and an examination of the deviance residuals to identify any outlier values.

Table 1. Description of study variables and sources

Variable Indicator	Description	Source
State adoption of a supportive stem cell research policy	Dummy variable (yes = 1) indicating whether a state adopts a supportive stem cell policy in this year	National Conference of State Legislatures (NCSL) data, legislative records, press releases
State adoption of a restrictive stem cell research policy	Dummy variable (yes = 1) indicating whether a state adopts a restrictive stem cell policy in this year	NCSL data, legislative records, press releases
Democrats gain control of legislature	Dummy variable (yes = 1) indicating a one-year shift from divided or Republican control of legislature to unified Democratic control	Calculations from NCSL
Republicans gain control of legislature	Dummy variable (yes = 1) indicating a one-year shift from divided or Democratic control of legislature to unified Republican control	Calculations from NCSL
Democratic governor	Dummy variable (yes = 1) indicating whether or not governor was a Democrat	State Politics & Policy Quarterly (SPPQ) data archive, National Governors Association (NGA)
Republican governor	Dummy variable (yes = 1) indicating whether or not governor was a Republican	SPPQ, NGA
Governor's institutional powers	Index representing combined tenure potential, budgetary powers, appointment powers, and veto powers of a governor	Beyle data (<http://www.unc.edu/~beyle/gubnewpwr.html> accessed 6 February 2013)
Abortion access index	Composite measure of state restrictions on access to abortion. Ranges from 0 (low access) to 4.3 (high access)	NARAL Pro-Choice America annual reports
Citizen ideology (liberalism)	Index of citizen ideology. A continuous variable with higher values indicating higher levels of liberalism	Berry data from Inter-University Consortium of Political and Social Research
Educational attainment	Percentage of adults over age of 25 with Bachelor's degree	US Census
Number of institutions high in federal R&D funding	Number of institutions greater than one standard deviation above mean in federal R&D expenditures for that year	Calculations from NSF WebCASPAR data
NIH funding per capita (lagged and logged)	NIH dollar awards per capita (lagged and logged)	NIH, US Census
State R&D expenditures per capita (lagged and logged)	State R&D expenditures to universities per capita (lagged and logged)	NSF WebCASPAR, US Census
Patents per 10,000 citizens (lagged and logged)	Number of utility patents awarded to a state annually per capita (lagged and logged)	US Patent and Trademark Office, US Census
GSP per capita (lagged and logged)	Annual measure of GSP per capita (lagged and logged)	Bureau of Economic Analysis
Number of contiguous states with a restrictive hESC policy	Number of contiguous states that have previously adopted a restrictive hESC research policy	Calculations from dependent variable and maps
Number of contiguous states with supportive hESC policy	Number of contiguous states that have previously adopted a supportive hESC research policy	Calculations from dependent variable and maps

5. Findings

Table 2 presents descriptive statistics for the independent variables from Table 1 for all 47 states in the first and last year of the analysis.

Table 3 lists the states that adopted supportive stem cell policies during each year of the analysis, the number of states in the risk set, the survivor function, and the hazard rate. Table 4 presents the same information for restrictive stem cell policies. All told, 12 states adopted supportive policies during the time period of our analysis and eight states adopted restrictive policies. These 20 adoptions were distributed among 18 states, as two states (Michigan and Iowa) first adopted a restrictive policy and then later changed to a supportive one. Overall, 29 of the 47 states included in our analysis had adopted neither a supportive nor a restrictive stem cell policy by the end of 2008.

After Rhode Island's adoption in 1998, few supportive policies were successfully adopted till the mid 2000s, when six states adopted these policies in the years of 2005 and 2006. Following these peak years, states continued to adopt supportive policies, with two states adopting such policies in 2007 and one state in 2008. This slowdown in adoption may reflect a more cautious attitude taken by state governments as the 2008 presidential elections, and a likely change in federal stem cell policy, approached. In contrast, Michigan was the first state to adopt a restrictive

Table 2. Descriptive statistics (n = 47 states)

	1998	2008
Democrats gain control of legislature	0.00	0.04
	(0.00)	(0.20)
Republicans gain control of legislature	0.00	0.02
	(0.00)	(0.15)
Democratic governor	0.30	0.60
	(0.46)	(0.50)
Republican governor	0.68	0.40
	(0.47)	(0.50)
Governor's institutional power	3.47	3.49
	(0.45)	(0.45)
Abortion access index	1.53	1.67
	(1.46)	(1.65)
Citizen ideology (liberalism)	49.39	53.47
	(14.22)	(15.89)
% of population aged 25 or more with 4-year college degree	0.24	0.29
	(0.05)	(0.06)
Number of institutions high in federal R&D funding (lagged)	2.45	2.77
	(2.67)	(2.73)
NIH expenditures per capita (lagged and logged)	3.40	3.94
	(1.03)	(0.81)
State R&D expenditures per capita (lagged and logged)	2.09	2.29
	(0.76)	(0.62)
Patents per 10,000 citizens (lagged and logged)	0.56	0.63
	(0.65)	(0.74)
GSP per capita (lagged and logged)	10.57	10.71
	(0.17)	(0.18)
Number of contiguous states with restrictive stem cell policy	0.06	0.79
	(0.25)	(0.88)
Number of contiguous states with supportive stem cell policy	0.04	0.94
	(0.2)	(1.13)

Table 3. States adopting a supportive stem cell policy with Kaplan-Meier survivor function and hazard rate

Year	States adopting supportive stem cell policy	Number of adoptions	Cumulative adoptions	Risk set	Survivor function	Hazard
1998	RI	1	1	46	0.979	0.002
1999		0	1	46	0.979	0.000
2000		0	1	46	0.979	0.000
2001		0	1	46	0.979	0.000
2002	CA	1	2	45	0.957	0.004
2003		0	2	45	0.957	0.000
2004	NJ	1	3	44	0.936	0.006
2005	CT, IL, MA	3	6	41	0.872	0.022
2006	MD, MO, WI	3	9	38	0.809	0.032
2007	NY, IA	2	11	36	0.766	0.036
2008	MI	1	12	35	0.745	0.056

stem cell policy in 1998. Adoption of restrictive policies continued at an even pace for several years, before peaking in 2003 and 2005, both of which had two adoptions. Figs 1a and 1b display these hazard rates across the time period in our study.

Table 4. States adopting a restrictive stem cell policy with Kaplan-Meier survivor function and hazard rate

Year	States adopting restrictive stem cell policy	Number of adoptions	Cumulative adoptions	Risk set	Survivor function	Hazard
1998	MI	1	1	46	0.979	0.002
1999		0	1	46	0.979	0.000
2000	SD	1	2	45	0.957	0.003
2001		0	2	45	0.957	0.000
2002	IA	1	3	44	0.936	0.004
2003	AR, ND	2	5	42	0.894	0.009
2004		0	5	42	0.894	0.000
2005	AZ, IN	2	7	40	0.851	0.014
2006		0	7	40	0.851	0.000
2007		0	7	40	0.851	0.000
2008	LA	1	8	39	0.830	0.050

Table 5 presents the results of the Cox proportional hazards models for the adoption of supportive and restrictive stem cell policies. While neither states' economic conditions nor demographics had a discernible effect on policy adoption, our model suggests the influence of several other of our hypothesized effects. Partisan politics and the strength of a state's scientific community, for instance, influenced the adoption of both supportive and restrictive stem cell policies. In contrast, the abortion access index was predictive only of the adoption of restrictive policies while policy adoption in neighboring states was only found to influence the adoption of supportive policies.

Partisan politics, as expected, closely followed our hypothesized influence where a takeover of the state legislature by Democrats was a strong predictor of the adoption of supportive policies, while a Republican takeover was predictive of the adoption of restrictive policies. The effect of partisan takeover on the hazard rates and the influence of the abortion score are shown in Fig. 2.

While the legislative takeover variables had significant and straightforward effects in both models, the effects of the governor variables were more nuanced and somewhat counterintuitive to our initial thinking. Recall that because of our two policies we interacted our partisan gubernatorial indicator with that of governor's power, so as to relate to the typical partisan distinctions in these policies. In the analysis of restrictive policies, each of the three variables related to the governor were found to influence adoption, with the interacted terms being 'jointly significant.' Fig. 3 contrasts Democratic and Republican governors at different levels of institutional powers.[7] The coefficients on these three variables indicate that, at low levels the presence of a Republican governor typically increases a state's propensity to adopt a restrictive stem cell policy, but that this

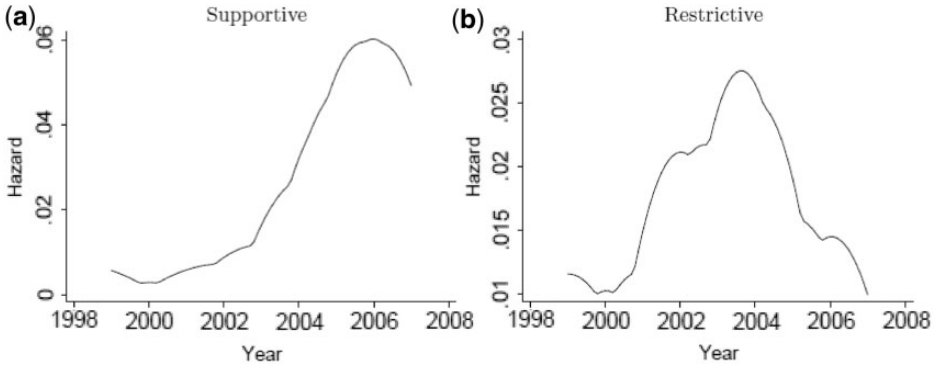

Figure 1. Smoothed hazard estimates for adoption of supportive and restrictive stem cell policies.

Table 5. Results from Cox proportional hazards model for state adoption of supportive and restrictive stem cell policies

	Variable	Supportive policy	Restrictive policy
State electoral politics	Democrats gain control of state legislature	2.34**	
		(0.61)	
	Republicans gain control of state legislature		1.83^{+}
			(1.09)
	Democratic governor	−11.33	
		(8.63)	
	Republican governor		13.75^{+}
			(7.34)
	Governor's institutional powers	−0.06	4.89*
		(1.44)	(1.94)
	Interaction between Democratic governor and governor's powers	3.62	
		(2.21)	
	Interaction between Republican governor and governor's powers		−3.43^{+}
			(1.89)
State morality policy	Abortion access index	−0.02	−0.86^{+}
		(0.20)	(0.45)
State scientific characteristics	Number of strong research institutions (logged)	2.80*	−0.45*
		(1.39)	(0.19)
	Interaction between number of strong research institutions and time	−1.19^{+}	
		(0.65)	
	NIH expenditures per capita (lagged and logged)	1.44	−0.32
		(1.08)	(0.45)
	State R&D expenditures per capita (lagged and logged)	−21.57*	1.04
		(10.45)	(0.74)
	Interaction between state R&D expenditures and time	9.37^{+}	
		(5.07)	
State economic conditions	Patents per 10,000 citizens	−0.22	−0.44
		(1.30)	(0.57)
	GSP per capita (lagged and logged)	4.14	3.71
		(2.83)	(2.86)
State population characteristics	Citizen ideology (liberalism)	0.06	0.04
		(0.04)	(0.04)
	Educational attainment	3.11	−11.29
		(17.33)	(10.56)
Policy diffusion variables	Number of contiguous states with supportive policy	−0.35	0.27
		(0.43)	(0.59)
	Number of contiguous states with restrictive policy	1.00*	−0.39
		(0.43)	(0.39)
	N	480	477
	Chi^2	320.79	38.97

** = $P < 0.01$, * = $P < 0.05$, $^{+}$ = $P < 0.10$

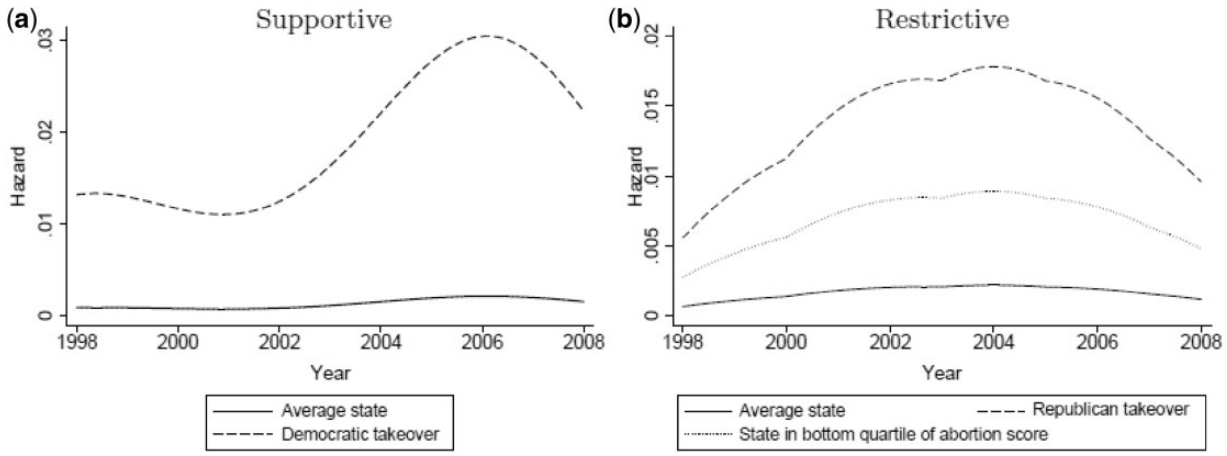

Figure 2. Effect of legislative takeover and abortion index on adoption of stem cell policies.

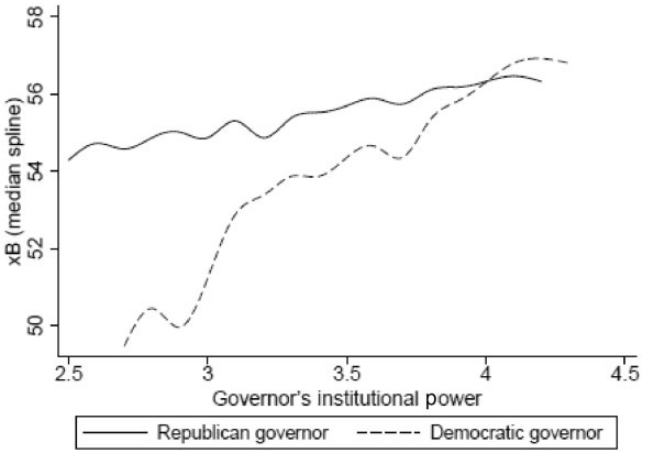

Figure 3. Effect of governor's party and powers on adoption of restrictive stem cell policies.

difference between the parties decreases as governors' institutional powers increase. This relationship runs somewhat counter to our more simplistic thinking wherein states with 'strong Republican governors' would be more apt to adopt restrictive policies. This relationship between the political party of a state's governor, the governor's institutional powers and the adoption of a restrictive policy is illustrated in Fig. 3. In the analysis of supportive stem cell policies the coefficients on the governor variables were not individually significant.

Variables were also included in the models to test our hypothesis that the strength of a state's scientific community might influence the adoption of stem cell related policies. We found that the number of highly ranking R&D institutions in a state did influence the adoption of both supportive and restrictive stem cell policies and these effects were generally in the direction we predicted. The variable violated the Cox proportional hazards assumption in the analysis of supportive policies, leading to the inclusion of a time interaction variable. Fig. 4a shows the combined effect of these two interacted variables. In 1998, the 95% confidence intervals contain zero, making it difficult to draw an inference about the influence of these institutions. However, in the period 1999–2005, the 95% confidence intervals no longer contain zero, instead showing a positive, albeit diminishing, effect across time, an effect that continues downward until 2006 when the confidence intervals again contain zero. Considering this interaction effect, our analysis found that states with a higher number of strong research institutions were more likely to adopt supportive policies early in the time period we studied, but this effect reduced in magnitude over time. In contrast, states with more strong research institutions were less likely to adopt restrictive policies across the time period we studied (see Fig. 4b). The NIH expenditures per capita variable was not significant in either analysis.

In addition to the variables focusing on federal funding of science in each state, we included state R&D expenditures per capita in our analysis. This variable did affect the adoption of supportive state stem cell policies, but did not affect the adoption of restrictive policies. Our diagnostics indicated that the influence of this variable on the adoption of supportive policies changed over time. In the early years of our analysis, states with higher R&D expenditures per capita were less likely to adopt supportive policies, but this effect lessened over time and, by 2006, this effect was no longer significant (data not shown).

Variables capturing the policy environment in neighboring states were included in our analysis to assess how, if at all, external considerations influenced the adoption of state stem cell policies. There was no support for our hypothesis that competitive advantages would move states to adopt supportive policies after their neighbors had done so. We did find, however, that the prior adoption of restrictive stem cell policies by neighboring states influenced the adoption of supportive policies. All else being equal, the more neighboring states that had adopted restrictive policies, the more likely a state was to adopt a supportive

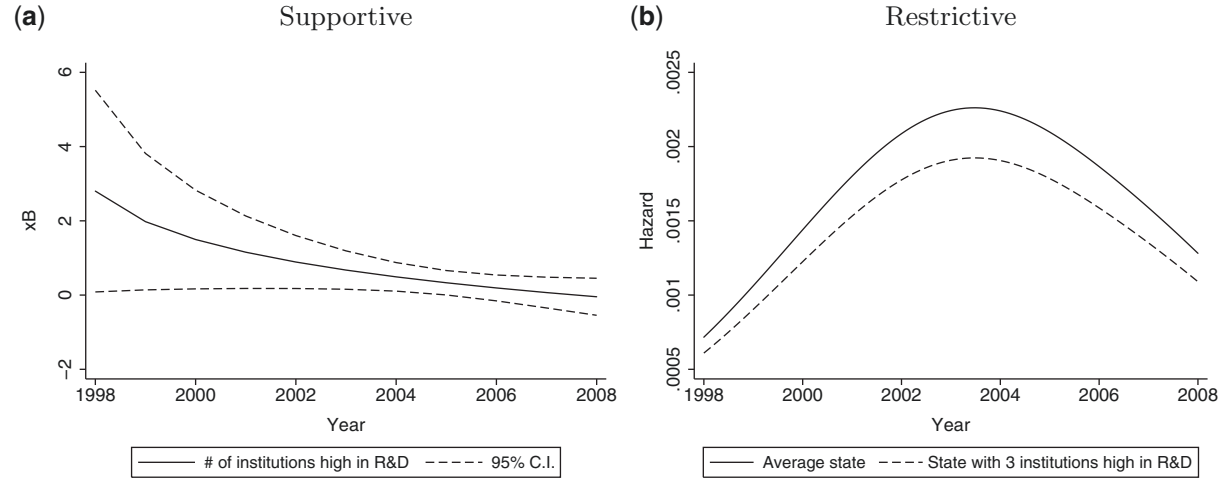

Figure 4. Effects of high R&D institutions on stem cell policy adoption.

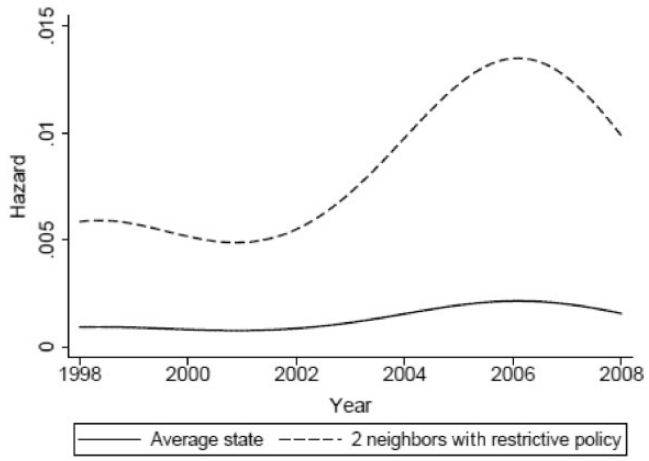

Figure 5. Effect of stem cell policies in neighboring states on adoption of supportive stem cell policies.

policy of its own (see Fig. 5). We did not find significant contiguity effects on the adoption of restrictive policies. Scholars of policy diffusion among states have utilized various specifications of a state's diffusion partners. We choose to focus on counts of neighboring states in this analysis because of the possibility for scientific recruitment created by these policies and our belief that policy action on a contentious issue, such as stem cell policy, likely catches the attention of policy-makers in neighboring states and raises the prominence of this topic on a state's policy agenda. We also explored other specifications, including states within a census region and division, but we did not find substantively different results.

6. Conclusions

Our analysis identified several types of factors—including elective politics, prior morality policies, the existing scientific community and the policy environment in neighboring states—that influence the adoption of supportive and restrictive state stem cell policies. In our analysis, political factors and the strength of the scientific community affected the adoption of both supportive and restrictive policies, while prior morality policies affected only restrictive policies and the policy environment in neighboring states affected only the adoption of supportive policies.

Most of the factors we identified as playing significant roles in the adoption of supportive state stem cell policies acted in the direction we hypothesized. Transition from Republican or mixed control of the state legislature to Democratic control was a strong predictor of supportive policy adoption, for instance. This finding aligns with national politics, where Democrats have generally been supportive of hESC research and led attempts to overturn the federal funding restrictions put in place by former-President George W. Bush.

The number of strong research institutions in a state was also a strong predictor of the adoption of a supportive state policy, although this effect waned over time. This may reflect a desire by state policy-makers to protect their strong research institutions from the challenges associated with the difficult federal funding environment, particularly given concerns early in the George W. Bush Administration that top stem cell scientists were leaving or at least considering leaving the USA in search of a more supportive policy environment (Levine 2006). It may also reflect a deliberate attempt capitalize on the uncertain funding environment by highlighting the strength of their research institutions to facilitate program development or expansion. The decline in this effect over time may reflect the removal of early adopters with many strong research institutions from the risk set. Alternatively, it may reflect the role that these powerful institutions can play in state policy formation. To our knowledge, almost all research institutions have some formal lobbying presence in state

capitals. Further, these institutions often have many alumni in state politics. We leave for future research the question of how post-secondary institutions engage in the policy-making process, only suggesting that it likely occurs through both formal and informal means.

Our analysis also identified a time-dependent effect of state R&D spending on the adoption of supportive state stem cell policies. Early in the time period of our study, states with large per capita R&D expenditures were less likely to adopt supportive policies, although this effect waned over time and disappeared before the end of our analysis. This trend may reflect a changing view of stem cell science in state legislatures. It may be the case, for instance, that government officials in states with high per capita R&D funding initially thought they had already done enough to support science, but that over time, as stem cell science grew in stature and captured the sustained attention of the public, they reconsidered this position.

In addition to these internal characteristics, we also found a role for external factors in the adoption of supportive state stem cell policies. Specifically, we found that prior adoption of a restrictive policy in one or more neighboring states had a strong positive effect on the adoption of a supportive policy. We interpret this effect as evidence of interstate competition. Previous literature suggests that stem cell scientists in restrictive states are particular mobile (Levine 2008) and our finding may reflect strategic action on the part of state officials to place research institutions in their states in a strong position to recruit stem cell scientists away from their restrictive neighbors. Alternatively, it could reflect a form of policy learning, where states are choosing not to emulate their neighbors but rather to innovate in a different direction, perhaps to avoid the controversy or turmoil associated with the adoption of a restrictive policy. To our knowledge, this form of diffusion—where competition and/or learning manifests itself in states innovating away from their neighbors—has not been reported previously and warrants further examination, perhaps through state-specific case studies.

In the analysis of the adoption of restrictive policies, partisan politics at both the legislative and gubernatorial levels also appears to influence adoption. Legislative takeover by Republicans and states with Republican governors were generally more likely to adopt restrictive policies. These effects were in agreement with our hypotheses as restricting stem cell science has typically been a position associated with the Republican Party at the national level.

Adoption of restrictive policies was also related to states' positions on another area of morality policy: reproductive rights. States that received low scores on NARAL's reproductive rights index (e.g. states that have restricted access to abortion services and contraceptives) were more likely to adopt restrictive policies. As the ethical controversy surrounding hESC research touches on many issues found in the abortion debate, this link suggests that state stem cell policy, at least in its restrictive forms, can rightly be considered a type of morality policy.

Our analysis also found that the number of strong research institutions in a state was a predictor of the adoption of restrictive stem cell policies. In this case, the more strong research institutions present in a state, the less likely that state was to adopt a restrictive stem cell policy. This may reflect decisions by state policy-makers to avoid action that would negatively impact the state's top research institutions and potentially imperil the economic development and prestige associated with possessing such environments. As discussed previously, this result may also reflect the important role of research institutions in state policy-making and suggests a need for greater study of the role of research institutions in the formulation of science and technology policy.

Comparing the variables affecting the adoption of supportive policies with those affecting the adoption of restrictive policies lends support to the idea that supportive policies are primarily a form of economic development policy, while restrictive policies cross into the domain of morality policy. This result is seen most clearly by comparing the positive relationship we find between the number of strong research institutions in a state and the adoption of supportive policies with the absence of any significant effect for the abortion access variable. The importance of this economic development framing can be seen in the development of economic impact projections in states debating supportive policies (Baker and Deal 2004; Goodman and Berger 2008; Seneca and Irving 2005) and discussions in the media and literature about these projections (Beasley and Anderson 2004; Longaker et al. 2007). This case for considering restrictive policies to be a form of morality policy is based on our finding that states with more restrictions on access to abortion were more likely to adopt restrictive policies, combined with our finding that states with more strong research institutions were less likely to adopt restrictive policies.

These results reveal an interesting tension between morality politics and economic development in states that restrict access to reproductive services, but have large numbers of strong scientific institutions. In these states, we would expect the same considerations that led to restrictions on abortion to push the states toward the adoption of restrictive policies, but, at the same time, the strong research infrastructure would discourage the adoption of restrictive policies and encourage the adoption of supportive policies. In total there are seven states in the top quartile for the number of strong research institutions and the bottom quartile for the reproductive rights index. Examination of these states reveals a number of strategies to address this tension. In Texas, for instance, numerous bills both supporting and restricting stem cell research have been proposed, although no stem cell policy has been adopted (Matthews and Rowland

2010). Texas has, however, adopted a large state funding program focused on cancer research (Finkelstein 2008). This program appears to be modeled after California's stem cell program and its existence allows Texas policy-makers to demonstrate their support for science without adopting a more contentious stem cell policy. Two other states in this select group (Ohio and Indiana) have adopted programs to support adult stem cell research. This research is important, but much less contentious than hESC research and not affected by the federal funding restrictions. For this reason, these programs can be seen as a compromise approach to balance the competing moral and economic imperatives. Michigan, one of the two states to have adopted both a restrictive and supportive policy during the period of our study, also falls in this group of states with large numbers of strong research institutions and low scores on the reproductive rights index.

In addition to the internal determinants of policy adoption, our analysis considered four possible effects of the policy environment in neighboring states. Only one of these four —the effect of the number of neighboring states with restrictive policies on the adoption of supportive policies—was found to influence adoption. We interpret this finding as evidence of particular form of interstate competition. The lack of confirmation for the other forms of policy diffusion may indicate that internal characteristics of the state better frame the morality policy and economic development adoptions better than policy in neighboring states. Alternatively, it may be the case that states look not to their neighbors but to states they consider 'scientific peers' when considering the adoption of science and technology policies. If this is the case, the adoption of a stem cell policy by Massachusetts, for instance, may be more influenced by the adoption of policies in California, Maryland and New York, than by any policy action in New Hampshire or Vermont. This concept of scientific peers would, however, need to be more fully defined, before such a hypothesis could be tested.

The adoption of state stem cell policies can also, of course, be influenced by external, macro-level events other than state policy adoptions, a phenomenon that may contribute to our need to include numerous time interactions in this study. The federal funding policy for hESC research adopted during the Bush Administration influenced the introduction of stem cell bills in state legislatures (Karch 2012) and it seems likely to have also played a role in the adoption of state policies. Several of the states that adopted supportive policies justified their policies, at least in part, on the basis of a desire to circumvent federal funding restrictions. Given this rationale, it will be interesting to see if these state programs continue now that President Obama has partially relaxed the funding restrictions adopted by his predecessor. In addition, states that were satisfied with the funding environment under President Bush but dislike the current, more permissive federal environment may be inspired to adopt restrictive policies. While our analysis provides insight into the adoption of state stem cell policy in the initial decade of this research, these considerations suggest the field is likely to continue changing and should remain of interest to policy scholars well into the future.

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Notes

1. Although we focus our analysis on policies that affect human embryonic stem cell research, for the sake of simplicity, we will refer to the policies we study as supportive or restrictive stem cell policies. As discussed later, we exclude a handful of state policies that affect only research on non-embryonic stem cells from our analysis, as these policies raise a different set of issues.
2. Recent research on induced pluripotent stem cells, essentially non-embryonic cells that are converted into cells that exhibit many of the properties of hESCs may provide a less-controversial alternative to therapeutic cloning.
3. See P.L. 104-99 110 Stat 26 for the original language of this amendment. The amendment has been included every year since Fiscal Year 1996 as a rider to the Department of Health and Human Services Appropriations Bill.
4. Perhaps not surprisingly, some states have wavered over time in their policy stances toward stem cell issues, and some have indeed created opposing policies.
5. Although neither Alaska nor Hawaii has adopted a stem cell policy, Nebraska had adopted a restrictive policy, banning the use of state funds for hESC research. Necessarily, Nebraska's adoption of a restrictive policy was included in the creation of the diffusion indicator values for other states.
6. No states first adopted a supportive policy and then switched to a restrictive one.
7. This graphic was generated through running simulations that hold all variables, except the component terms and of the interaction term at their mean. The main effects of the interaction were then allowed to vary across all possible combinations and interacted. The graphic is the results of the predictions of these simulations, using a median spline smoother.

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